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TECHNICAL CHANGE AND EMPLOYMENT IN THE STEEL, AUTO, ALUMINUM, COAL, AND IRON ORE INDUSTRIES

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INTRODUCTION

Technical change, for all the good it does for society, is not an unmixed blessing. Though it leads to the development of useful new products and new production processes, it may impose hardships on those who use old, and no longer efficient, methods or produce products that are no longer wanted. The net effect of technical change on workers is hard to predict. They can gain if their industries gain in competition with producers of similar products. As consumers, they also gain from increases in productivity; they are able to buy things at lower prices. But if workers cannot adapt to new production methods and lose their jobs as a result, they can end up as net losers.

It is the prospect of direct substitution of machines for people in production--process innovation--that has been the focus of most concern about technical change. This concern is not new; it can be traced back to the Luddites in the early 1800s and continues today with the current fears about programmable robots. But whether changing processes is actually an important source of displacement, even in older plants, is not clear. In many cases, other factors--including increasing wages and prices of energy, import competition, changing preferences, and the business cycle--may have more to do with displacement than changing production methods.

In this paper, we present estimates of how labor demand was affected by changing production technology in five U.S. industries: steel, autos, aluminum, coal mining, and iron ore. These five industries are representative of basic "smokestack" industries that are often perceived as losing out to foreign competitors that are technologically more innovative. Steel and autos are two of the largest and most important U.S. manufacturing industries, both in terms of output and employment. Aluminum, though substantially smaller, competes directly with steel in many markets, including auto production. The iron ore and coal mining industries each produce an input for steel. Metallurgical coal is made into coke, which is used in blast furnaces to produce iron. Iron, in turn, is refined into steel.

All of these industries have, over the period studied (1958-1977), experienced technological innovation: changes in production methods such as adoption of the basic oxygen furnace and continuous casting in steel, pelletizing of iron ore, and "Detroit automation" and use of industrial robots in the auto industry. At the same time, their employment experience has been mixed. Employment grew in the auto and aluminum industries, but was stagnant or even declining in the other three industries. This mixed pattern makes it difficult to relate technical change and employment. Technical change might have decreased employment by displacing workers with new machines and equipment; or, it might have increased employment by helping to keep these industries competitive in world markets.

To measure the effects of technical change, we used an econometric model in which the level of technology in an industry was included as a determinant of cost. In this context, technical change has at least two definitions. It is common practice to define technical change by referring to the number of new machines or new processes. This is the definition we use to create a "direct measure" of technology. The definition used in economics is a shift in the cost function so that, at constant factor prices, different factor amounts are used. Neutral technological advance means that all factor input use is reduced proportionately. Labor-saving technical change involves a change in such a way as to use less labor, relative to other factors, at given factor prices.

The presence of machinery and equipment incorporating new technology is often used as evidence of a "technical change" having occurred within an industry. Rather than reflecting technical change, however, new equipment may represent substitution against other factor inputs--labor or materials--whose prices have been rising. Thus, "biases" in technical change may really represent factor substitution operating over the long run through changes in technology.

If process innovation leads to technical change, it also will result in an increase in total factor productivity: output per unit of input where all inputs are considered together. Changing technology is

not the only determinant of productivity growth; there are actually two components. One is the rate of technical change; the other is the relationship between changes in industry cost and changes in output. This latter relationship is commonly termed "returns to scale." Most researchers assume that, in long-run equilibrium, returns to scale are constant so that industry average cost does not depend on output. If the assumption of constant returns to scale is correct, there is no effect of scale on productivity so that the rate of productivity growth is the same as the rate of technical change. If there are increasing returns to scale, then assuming that returns are constant will lead to an overstatement of the rate of technical change.

As part of our study, we have investigated the relationships among technical change, new process innovation, and total factor productivity. Besides being able to determine the relationship between productivity growth and technical change, we were able to determine whether the adoption of new equipment was the sole determinant of technical change or if it resulted from unmeasured and gradual change for which a time trend is the best proxy.

THE EFFECT ON LABOR

Our primary concern has been to measure the relation between technical change and labor demand. Labor demand can change for reasons other than changing technology: either because relative input prices change leading to input substitution or because industry output

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changes. To isolate and measure the effects of technical change, these other determinants must be taken into account. Technology's effects work in two ways: (1) by increasing productivity for all factors, i.e., reducing the total bundle of inputs needed to produce a given output (the rate of input reduction is commonly called the "rate" of technical change), and (2) by shifting demand away from one input and toward another (the "bias" in technical change).

The combined effect on labor of the overall rate and bias in technical change is measured by the percentage change in labor demand when technology increases by one unit. The effect is "partial" in the sense that other variables that might affect employment (i.e., factor prices and output) are being held constant. Industry technical change can also affect labor demand indirectly by lowering the price of industry output, causing the quantity of output demanded to rise, which raises the demand for labor. This indirect effect is called the "output enhancement" effect of technology. The net effect of technical change will therefore depend upon which effect, i.e., partial or output enhancement, is greater.

While it is straightforward to define a labor demand function with parameters that allow the calculation of the partial effect of changes in technology, estimation of the necessary parameters is not so simple. The estimation must be based on a model that is flexible enough

to consider the demand for a number of different factors of production. Such models--including the "translog" cost model used here--have only recently entered the economic literature. Here, cost is assumed to depend upon the prices of factor inputs, the level of industry output, and the level of technology.

The cost model for the steel, auto, and aluminum industries included five inputs--production labor, nonproduction labor, capital, energy, and materials--in the cost function and imposed no restrictions on how the inputs could be substituted for each other. We assumed the firms minimized cost and then estimated how technical change has affected the individual industries. The manufacturing industries studied were defined at the 4-digit SIC level, a lower level of aggregation than that used in most industry studies. For example, the 4-digit industry for basic steel is 3312, which includes the largely integrated producers of carbon steel, but excludes stainless or specialized alloy steel and firms specializing in one stage of production, such as rolling. For coal mining and iron ore, data were not available for the full set of inputs. We therefore estimated a simpler labor demand equation directly.

The equations in the econometric system estimated for the three manufacturing industries included the cost function itself and equations for the share in cost of each input. Each share equation expresses an input's share in total cost as a function of input prices, output, and

technology. The share equations may be viewed as describing how input-output coefficients (also measured as input cost relative to total cost) move over time. More important, the equations also describe why the coefficients move. They explain changes in input-output coefficients in terms of: (1) adoption of new techniques, (2) changes in input prices, and (3) changes in scale.

For labor, the share equation describes how changes in the ratio of payroll to total cost depend upon changes in the wage rate, other input prices, output, and the level of technology. The estimated effect of a change in any variable on labor's share was obtained from the regression analysis. For example, technical change is described as labor-saving, labor-using, or neutral if the parameter on technology is negative, positive, or zero. In our model, labor-saving technical change means that as technology increases, the share of payroll in total cost goes down (all other exogenous variables held constant). The estimated effects on labor's share can then be used to derive the effect of technical change on the demand for the quantity of labor.

Implications concerning factor substitution and input adjustment may also be drawn from the regression analysis. The fact that the model considers all inputs, not just labor, is important; the results for the other inputs serve as a useful check on the theory and assumptions used in the model, and they also illuminate the nature of cost and production in each industry. For example, it is possible to check the often used

assumption that the cost function is characterized by constant returns to scale. If returns to scale are constant, then all inputs change in the same proportion as output, all else equal.

While, conceptually, the assumption of constant returns to scale or, equivalently, constant average cost over the long run, may seem reasonable, it turns out to be incorrect in many time-series applications. Because of slow adjustment, certain key inputs may be used in fixed amounts in the short run, even in response to changes in output. As a result, measured returns to scale will be increasing, not constant as is often assumed. Since productivity gains can result from increases in scale, as well as from technical change, it is important to distinguish between the two sources of productivity growth; to simply assume constant returns to scale will overstate the effects of technical change.

Our econometric approach, which involved estimating the degree of scale economies rather than assuming that returns were constant, also enabled us to determine which inputs moved proportionately with output and which did not. The presence of a relatively large and slowly adjusting capital stock in an industry means that the measured returns to scale will be biased upwards (so that the measured rate of technical change will be too low). Our results show that all three manufacturing industries have capital stocks that are relatively fixed in the short run, but the problem is most serious for the capital-intensive

aluminum industry. To obtain better measures of scale and technical change, we extended the model to allow for a slowly adjusting factor input.

THE MEASUREMENT OF INDUSTRY TECHNOLOGY

In addition to allowing measurement of productivity growth and its components, the econometric approach used in the project also allowed a test of different measures representing the level of industry technology. The standard approach has been to represent the level by a time trend. This is satisfactory if changes in technology unfold regularly and gradually. It is unsatisfactory if new processes are introduced rapidly and erratically. The distinction between the two measures is important since sudden or unexpected shifts in production processes and labor demand may make adjustment difficult for the industry's work force, whereas gradual change can be more readily accommodated.

To be as precise as possible, we therefore constructed direct measures of technology for producing steel, autos, coal, and iron ore.* For steel, we focused on three new technologies: (1) the basic-oxygen furnace (BOF), (2) oxygen lancing in open-hearth furnaces, both

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* Our strategy for measuring technical change was to measure the extent of adoption of well-publicized changes in technology. From this point of view, aluminum provides an interesting and valuable comparison; in our period of study, there has not been a well-publicized change in the aluminum industry. Thus, if technical change is, in general, the primary source of productivity growth and changes in technology lead to high rates of technical change, then steel and autos should have shown more rapid productivity growth than the aluminum industry.

of which are important in the steel-making process, and (3) the pelletization of iron ore. Data on the adoption of these innovations have been combined into a single index, weighted by the percentage that each is expected to reduce costs.

In the auto industry, technical change since World War II has involved the substitution of machines for workers in production processes such as welding. To quantify the concept of automation, we measured the stock of transfer machines, the basic unit of what was known as "Detroit Automation." A transfer machine performs several operations, each of which would otherwise be performed at different stations on the production line. We constructed an index of the number of transfer machines (adjusted to take account of the complexity and size of the individual machines) expressed as a ratio to the auto industry capital stock.

For the iron ore industry, we experimented with a number of different measures of output and its degree of processing. The measure we ultimately used was the one that turned out to have a significant effect on the demand for labor--the fraction of tonnage taken from open-pit mines as opposed to underground mines.

In coal mining, there are two basic methods: underground and surface. We constructed a separate measure of technology for each method. In underground mining, the important steps are cutting,

loading, and hauling away the coal. Technical change has been concentrated in cutting and loading. Our measure of technology for underground mining is the fraction of production carried out by the newer methods: continuous, shortwall, and longwall mining.

Surface mining involves cutting, loading, and hauling, and the removal and replacement of overburden, the material covering the coal. The main form of technical change in surface mining has been increased equipment capacity at all stages of the mining process. Our direct measure of surface mining technology is the percent of power shovels and dragline excavators with a bucket capacity of 6 yards or more.

EMPIRICAL RESULTS OF THE COST MODEL

The empirical work was primarily designed to measure the three effects that changes in technology can have on labor: (1) the bias in technical change, explained earlier as a change in relative factor demand at given factor prices and output; (2) the rate of industry technical change, which reduces total factor input demand; and (3) the extent to which new technology increases industry competitiveness and therefore output and employment. The first two effects combine to make up the "partial" effect of technical change, while the third is the "output enhancement" effect.

In the three manufacturing industries--steel, autos, and aluminum --we generally find strong evidence of labor-saving technical change.* In these industries, the share of payroll in total costs has been decreasing throughout the period of our study. The share of capital has been rising, evidence of capital-using technical change.** We find little evidence of substitution between labor and capital in response to current factor prices.

One interpretation of these findings is that when the price of labor increases relative to that of capital, little short-term substitution of capital for labor takes place, but over the long term it encourages advanced technologies that allow production to be less labor intensive. Thus, we hypothesize "induced innovation" biased away from labor and toward new capital. This induced innovation has not yet been identified empirically, but generalizations of our model may help quantify the link between new technologies and their determinants.

The estimation of the cost model enabled us to determine which component of productivity growth--i.e., the scale related component or the rate of technical change--contributed more to changes in productivity over time.

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* The only exception is autos when technology is measured directly.
** The exception, again, is autos when technology is measured directly.

We illustrate our decomposition of productivity growth using estimates for steel and autos, presented in table 1.* The components were estimated for three subperiods and for the entire time period. In steel, the estimated productivity growth for the 1959-77 period is made up almost entirely of the scale component; technical change is close to zero on average. When the subperiods are calculated separately, the scale related increase in productivity and the rate of technical change decrease over time. Indeed, over the 1974-77 time period, both contributed to a substantial decline in productivity growth, which averaged about -1.4 percent per year.

TABLE 1

CONTRIBUTIONS TO PRODUCTIVITY GROWTH
(STEEL AND AUTOS)

Time period	Average rate of productivity growth (%)		Scale effect (%)		Rate of technical change (%)	
	Steel	Autos	Steel	Autos	Steel	Autos
1959-77	.55	3.03	.55	1.24	.002	1.79
1959-1965	1.97	3.66	1.55	3.04	.42	.62
1966-73	.27	2.35	.39	.31	-.12	2.04
1974-1977	-1.39	3.29	-.90	-.04	-.49	3.33

The pattern in autos is different. The rate of productivity growth averages just over 3 percent a year for the entire period. Growth was

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* These numbers are based on regression estimates when the level of technology was represented by a time trend. It turned out that using the direct measure hardly changed the pattern or magnitudes of the two components for either industry. They were very similar to the time trend results.

rapid in the earlier period, fell in the middle period, and rose at the
end. The scale component decreased throughout whereas the rate of tech-
nical change increased throughout, attaining more than a 3 percent
growth rate over the last period while the contribution arising from
scale fell close to zero.

Changes in Labor Demand Over Time

Just as we were able to decompose productivity changes into scale
and technology effects, we were also able to decompose historical
changes in production worker employment into the effects arising from
changes in input prices, output, and technology.* Results for all five
industries are presented in table 2. For steel, autos, and coal mining,
there are two sets of results, one for the time trend measure of
technology and one for the direct measure. For aluminum, there was no
direct measure, and technology was represented by a time trend. For
iron ore, only the direct measure was used to represent technology.

Generally, the patterns are consistent across industries, regard-
less of the measure of technology. In every industry, advances in tech-
nology, holding constant output and input prices, reduced the demand for

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* Specifically, to determine the individual partial effects, we used the
econometric results to obtain a value for the percentage change in labor
demand arising from a change in a given exogenous variable (with the
other exogenous variables held constant). This was then multiplied by
the average actual percentage change in that variable over time.

TABLE 2

AVERAGE CHANGE IN PRODUCTION WORKER MAN-HOURS ATTRIBUTED
TO SPECIFIC EXOGENOUS VARIABLES

Industry (Measure of Technology)	P_L	P_N	P_K	P_F	P_M	Q	T	Total (= Σ)
Steel (Time Trend)	-.0205	.0115	.0029	.0004	.0054	.0156	-.0172	-.0019
Steel (Direct Measure)	-.0177	.0139	.0028	-.0002	.0032	.0156	-.0166	.0010
Autos (Time Trend)	-.0112	.0155	-.0061	.0008	.0017	.0585	-.0370	.0221
Autos (Direct Measure)	-.0306	.0129	.0088	.0017	.0094	.0387	-.0126	.0248
Aluminum	-.0459	.0134	--	.0029	.0380	.0817	-.0562	.0340
Coal (Time Trend)	-.0019	--	--	--	--	.0165	-.0340	-.0194
Coal (Direct Measure)	-.0011	--	--	--	--	.0162	-.0421	-.0270
Iron Ore (Direct Measure)	-.0064	--	--	--	--	.0005	-.0103	-.0162

production labor. The estimated reduction ranged from just over 1 percent each year in iron ore to over 5 percent in aluminum.*

The effect on employment of changes in production labor's own wage (holding constant other input prices, output, and technology) was also always negative and, at least in the three manufacturing industries, often larger than the effect of changes in technology. In contrast to the negative effects of changes in technology and wages, changes in output always increased labor demand. Labor demand also increased in response to increases in the wages of nonproduction labor (since production and nonproduction labor are substitutes in production). Increases in the price of capital, fuel, and materials taken individually affected employment very little. Taken together, increases in all three usually increased the demand for production labor (indicating substitutability between labor and these inputs).

In the mining industries, where labor demand equations were estimated directly, changes in technology had a negative effect on production labor, particularly in coal mining. The effect was somewhat higher when technology was measured directly, but generally, the results

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* For coal mining and iron ore, industries where labor demand equations were estimated directly, technical change was assumed to be Hicks-neutral, i.e., lacking any bias. The rate of technical change is therefore obtained as the negative of the coefficient on technology in the estimated labor demand equation. Though we do not present the equations in this paper (see [5]), the rate of technical change in coal mining, when a time trend represents technology, can be seen from table 2 to be equal to 3.4 percent.

for coal for all variables were close regardless of the measure of technology: changes in output had a positive effect and the own wage had a small negative effect. Overall, the total change in labor demand was negative, the major factor being changes in technology. The same was true in iron ore, although the magnitudes of individual effects were smaller in each case.

We conclude, therefore, that the partial effect of technology resulted in substitution against labor. It occurred in every industry studied. Increases in production workers' wages also led to a substantial employment decline in the steel, auto, and aluminum industries. At the same time, changes in output and other input prices in these same industries outweighed the negative effects leading to an overall increase in demand for employment. In iron ore and coal mining, the partial effect of technolog. outweighed the positive effects arising from changes in output.

The Output Enhancement Effect

Changes in technology have been shown to lead to reduced employment demand. However, the effect, as measured, occurred when output was held constant. To measure the total effect on employment demand, we must consider the way in which technology can lead to gains in employment. New technologies result in an increased supply at a given cost of production or, in other words, a downward shift in the industry supply curve. The equilibrium price falls, increasing the quantity of output

demanded and the demand for inputs at any given price.* The ultimate
change in labor demand depends upon which of the two effects of tech-
nology (i.e., the partial or output enhancement effect) is greater.

To measure the output enhancement effect, we constructed a simple
model that related output changes to changes in industry technology.
The demand for the domestic product was conditioned on the presence of a
competing, though not perfectly substitutable, import. Improvements in
industry technology were assumed to reduce cost and domestic output
price though import prices were treated as not responding. The change
in domestic price turned out to be the negative of the rate of change in
industry productivity, which meant that if technology increased, it
increased productivity and led to a fall in output price, increased
output, and increased labor demand.

The total effect of technical change on labor (holding input prices
constant) is therefore made up of the output enhancement effect and the
partial effect described in the previous section. Table 3 reports
average values of the the output enhancement, partial, and total effect
of technology over the 1959-1977 period. For steel, the output
enhancement effect is negligible regardless of whether technology is

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* It is important to distinguish this effect from the effect of output
in the previous section. There, labor demand increased in response to
increases in output, but the effect occurred when technology was held
constant. Now, however, we are measuring the response of output to
changes in technology that will, in turn, lead to increased labor
demand.

TABLE 3

THE EFFECTS OF TECHNOLOGY ON LABOR[a]
(All Industries)

Industry (Measure of Technology)	Output enhance-ment effect	Partial effect	Total effect
Steel (Time Trend)	-.0014	-.0172	-.0186
Steel (Direct Measure)	-.0017	-.0166	-.0183
Autos (Time Trend)	.0234	-.0370	-.0136
Autos (Direct Measure)	.0135	-.0126	.0009
Aluminum	.1318	-.0562	.0756
Coal (Time Trend)	.0365	-.0340	.0025
Coal (Direct Measure)	.0452	-.0421	.0031
Iron Ore	.0244	-.0103	.0141

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[a]To obtain values of the elasticity of demand, we relied on [4] for steel and [2] for autos. We were able to calculate the values of the elasticity as -1.01 and -1.12 in steel and autos, respectively. For aluminum, we used a value of -3, a relatively large value for the elasticity (which we derived from information in [3]). It implies that price effects will have a large effect on output. Finally, for coal mining, we derived an elasticity of -1.087. Details are given in [1].

measured by a time trend or directly. This, of course, is due to the
(almost) zero rate of technical change in steel (see table 1).
Employment is reduced by just over 1.8 percent a year.

For autos, the output enhancement effect is important, but differs
in magnitude in the two cases. When the time trend is used, the effect
is almost twice as large as in the direct measure case (as shown in [5],
this is partly a result of a higher rate of technical change). The
partial effect, on the other hand, is about three times as large, so the
total effect remains negative. The results illustrate the importance of
the output enhancement effect. If it is larger than the partial effect,
the net effect of technology becomes positive.

The calculated output enhancement effect for aluminum is large
--over 13 percent per year--and outweighs the partial effect of less
than -5 percent calculated earlier. It leads to a total effect on labor
greater than 7-1/2 percent per year. The effect is large, compared with
the other industries, because of the high (absolute) value for the
output demand elasticity. The high value of the elasticity means that
competition from imports (and secondary aluminum) is fierce, and any
relative price shift toward imports results in a large loss in domestic
output. Advances in technology therefore allow domestic producers to
remain competitive in price and keep output levels higher than they
would have been had they not innovated.

Finally, in the two mining industries, the output enhancement effects of technology are also substantial. In all three cases (i.e., two for coal and one for iron ore), the positive output enhancement effect outweighs the negative partial effect. In iron ore, where technology allowed the pelletization of iron ore, the effect is more than twice the partial effect, and so advances in technology lead to an growth in labor of almost 1.5 percent a year.

THE ROLE OF ATTRITION IN REDUCING DISPLACEMENT DUE TO TECHNICAL CHANGE

There is yet another factor that mitigates the negative effects on employment arising from changing technology--attrition. Whatever the source of the decline in employment, attrition can potentially lessen the amount of involuntary displacement. One measure of attrition is the industry quit rate, presented in table 4 for the five industries studied, as well as all manufacturing.

TABLE 4

QUIT RATE BY INDUSTRY[a]
(All Industries)

	Average annual quit rate (1973-1977) (%)
Steel	6.0
Autos	11.0
Aluminum	9.0
Iron Ore	9.0
Coal Mining	9.0
Manufacturing	24.0

[a]Source: Employment and Earnings, Bureau of Labor Statistics, U.S. Department of Labor.

The table illustrates how much primarily voluntary movement occurs in U.S. industries. Though the industries studied exhibit quit rates well below the average rate in manufacturing, these rates are still substantially greater than any decline in employment caused by changes in technology.

It is therefore possible that all reductions in the labor force due to technical change could be accomplished through attrition. This is not to say that technical change will never lead to layoffs. The effect of technical change on an industry's work force might be concentrated geographically, for example, in such a way as to lead to layoffs in one area, but with accessions occurring elsewhere. It is also possible that cyclical downturns, added to the effects of technical change, might overwhelm attrition as a means of reducing employment.

Still, the fact remains that the rate of attrition is far above the employment effects of technical change and therefore provides a cushion when employment declines occur. Even in steel, with the lowest quit rate (6 percent) and the largest drop in employment arising from technology (almost -2 percent) voluntary turnover is still more than adequate to cover the decline.

CONCLUDING REMARKS

Technical change's effects on employment include a partial effect and an output enhancement effect. Much of our work has dealt with obtaining better estimates of the partial effect, i.e., the employment change due to new technologies when output is held constant. An important consideration in developing our econometric model was that it allowed us to measure the effects of technical change and to distinguish these effects from those of scale economies. Had we not done so the effects of technical change would have been overstated.

The partial effect was negative in all industries, regardless of the measure of technology. The effect was strongest in the aluminum, coal mining, and auto (under the time trend specification of technology) industries and weakest in the iron ore industry. Steel, with a virtually zero rate of technical change, still experienced labor displacement due to new technology, but this apparently was solely the result of the installation of less labor-intensive production processes.

We also compared the effects of technical change and the implications for employment demand when alternative measures of technology, the time trend and a measure of new process innovation, were used in our models. In general, the way in which technology was measured did not affect the results very much; except for iron ore, the conclusions were substantively the same. While economists typically measure technology with a time trend, they are often attacked for having over simplified.

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Our results indicate that, in most cases, this simplification is reasonable.

The degree of labor displacement is potentially lessened by the output enhancement effect of new technology: New technology leads to lower output prices, increases in the quantity of output demanded, and increases in employment. Though the output enhancement effect was insignificant for steel (since the rate of technical change was near zero), for all the other industries, it led to employment growth that counterbalanced much of technical change's labor-saving characteristics. Once both the output enhancement and partial effect are accounted for, any decline in employment due to technical change was relatively small and did not typically move in great jumps from year to year. Normal labor turnover--retirements and quits--far exceeded the decline in employment caused by changing technology, allowing adjustment with minimal layoff of workers.

REFERENCES

[1] Bowes, Marianne. "Coal Mining." The Public Research Institute Working Paper 82-10, March 1982

[2] Charles River Associates. Cost-Benefit Analysis of the Effects of Trade Policies on Product and Labor Markets in the U.S. Automobile Industry. Report to the Bureau of International Labor Affairs, U.S. Department of Labor, Oct. 1975

[3] Charles River Associates, Inc. An Economic Analysis of the Aluminum Industry. Report to Property Management and Disposal Service, General Services Administration, Washington, D.C.

[4] Jondrow, James M. "Effects of Trade Restrictions on Imports of Steel." The Impact of International Department of Labor, Bureau of International Labor Affairs, Washington, D.C., pp. 11-25

[5] Levy, Robert A.; Bowes, Marianne; and Jondrow, James M. "Adjustment of Employment to Technical Change in Steel, Autos, Aluminum, Coal, and Iron Ore." Center for Naval Analyses, CRC 487, June 1983